# Optimal Electric Field Estimation for Exoplanet Imaging Observatories in Space

Completed Technology Project (2014 - 2018)

## Project Introduction

The discovery and characterization of Earth-like planets around other stars is a high priority in modern astronomy. While over 900 confirmed exoplanets have been discovered, all but a handful were found by indirect means such as stellar transits and radial velocity. Direct imaging is the only way to study the composition and habitability of exoplanets. The challenge of direct imaging is to prevent diffracted starlight from overwhelming the light of a dim exoplanet. As an example, the Earth is about 10 billion (1e-10) times dimmer than the Sun in visible light; for a Hubble-size telescope 10 parsecs away, the Earth would be about 1e-8 times dimmer than the diffracted starlight at the same location. A coronagraph can be used to reduce diffracted starlight in the area of the image where the planet may exist, which is called the search area. However, even the highest quality optics in a static system have aberrations that prevent better than about 1e-7 contrast between an exoplanet and its star. Therefore, all high-contrast imaging systems are designed with one or more deformable mirrors (DMs), which can actively correct these quasi-static aberrations and recover contrast in sub-regions of the search area known as dark holes. Unlike in ground-based adaptive optics (AO) systems that use a dichroic beamsplitter and a dedicated wavefront sensor to correct for atmospheric turbulence, the science camera at the focal plane must double as the wavefront sensor in high-contrast imaging to avoid non-common path aberrations. Current focal plane wavefront correction algorithms are not ready for use in space. The main priority to date has been to reach as high a contrast as possible. Several groups have already demonstrated contrast at the 1e-9 to 1e-10 levels with various coronagraphs in the past decade. However, the development of estimation and control algorithms has slowed during that same period. A space telescope using current wavefront correction algorithms would use all or nearly all of its time just creating the dark holes for one or two stars. This is worrisome because NASA is in pre-Phase A of a coronagraph instrument for the Astrophysics Focused Telescope Asset (AFTA), so we urgently need improved wavefront correction routines. Existing, deterministic wavefront control algorithms are already suitable for a space mission, but they depend on wavefront estimation algorithms that are neither complete nor fast enough. My doctoral research is focused on advancing wavefront estimation algorithms to meet the needs of a space mission. Exoplanets are incoherent with their host stars, but wavefront estimation algorithms have so far not included estimation of these very objects that we wish to study. I am developing several algorithms that will provide optimal estimates of incoherent sources during the iterative wavefront correction routine. Previous wavefront correction routines have also assumed a static (that is, unchanging over the course of several images) system. Exoplanet exposures will take hours to days, however, so I am developing the first wavefront estimator that incorporates the dynamics of thermal flexing of a space telescope. I am developing these and other new wavefront estimation algorithms at Princeton, where I will test them in the High Contrast Imaging Laboratory with two DMs and a shaped pupil coronagraph. I will use our


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## Table of Contents



## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Responsible Program:**

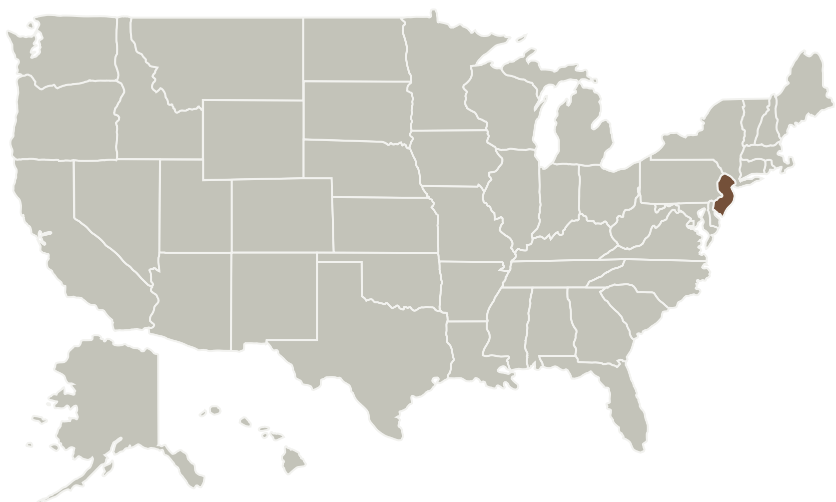
Space Technology Research Grants

star-planet simulator to inject a dim, incoherent source into the optical system, and I will add heaters to parts of the optical bench to induce thermal flexing. Wavefront correction is necessary for any high-contrast imaging system, so my research has strong potential for collaboration with groups at various research centers across the country. By addressing the limitations identified by NASA in wavefront correction and high-contrast imaging, my theoretical and experimental research will enable space telescopes to detect and characterize Earth-like exoplanets.

### Anticipated Benefits

By addressing the limitations identified by NASA in wavefront correction and high-contrast imaging, this theoretical and experimental research will enable space telescopes to detect and characterize Earth-like exoplanets.

### Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| Princeton University | Supporting Organization | Academia | Princeton, New Jersey |

| Primary U.S. Work Locations |
|---|
| New Jersey |

## Project Management

**Program Director:**

Claudia M Meyer

**Program Manager:**

Hung D Nguyen

**Principal Investigator:**

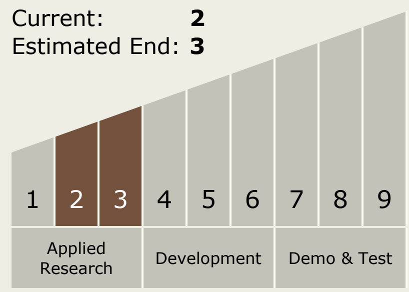
N Jeremy Kasdin

**Co-Investigator:**

A J Eldorado Riggs

## Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**




## Technology Areas

**Primary:**

- TX08 Sensors and Instruments
  └ TX08.1 Remote Sensing Instruments/Sensors
    └ TX08.1.1 Detectors and Focal Planes

## Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html